

(19)



Europäisches Patentamt  
European Patent Office  
Office européen des brevets



(11)

**EP 0 973 644 B1**

(12)

**EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention  
of the grant of the patent:

**22.01.2003 Bulletin 2003/04**

(51) Int Cl.7: **B41J 2/21, B41J 2/045**

(86) International application number:  
**PCT/GB99/00450**

(21) Application number: **99905036.2**

(87) International publication number:  
**WO 99/041084 (19.08.1999 Gazette 1999/33)**

(22) Date of filing: **12.02.1999**

**(54) OPERATION OF DROPLET DEPOSITION APPARATUS**

**BETRIEB EINER TRÖPFCHEN-NIEDERSCHLAGVORRICHTUNG**

**PROCEDE DE MISE EN SERVICE D'UN DISPOSITIF SERVANT A DEPOSER UNE GOUTTELETTE**

(84) Designated Contracting States:  
**AT BE CH DE DK ES FR GB IE IT LI NL SE**

(30) Priority: **12.02.1998 GB 9802871**

(43) Date of publication of application:  
**26.01.2000 Bulletin 2000/04**

(73) Proprietor: **Xaar Technology Limited**  
**Cambridge CB4 0XR (GB)**

(72) Inventor: **WEBB, Laura Anne**  
**Cambridge CB4 5RN (GB)**

(74) Representative: **Moir, Michael Christopher et al**  
**Mathys & Squire**  
**100 Gray's Inn Road**  
**London WC1X 8AL (GB)**

(56) References cited:  
**EP-A- 0 721 840** **EP-A- 0 737 586**  
**US-A- 4 503 444** **US-A- 4 513 299**

**EP 0 973 644 B1**

Note: Within nine months from the publication of the mention of the grant of the European patent, any person may give notice to the European Patent Office of opposition to the European patent granted. Notice of opposition shall be filed in a written reasoned statement. It shall not be deemed to have been filed until the opposition fee has been paid. (Art. 99(1) European Patent Convention).

## Description

[0001] The present invention relates to methods of operating droplet deposition apparatus, in particular an inkjet printhead, comprising a chamber communicating with a nozzle for ejection of ink droplets and with a supply of ink, the printhead further comprising electrically actuable means associated with the chamber and actuable a plurality of times to eject a corresponding number of droplets. In particular, it relates to a printhead in which the chamber is a channel having associated with it means for varying the volume of the channel in response to an electrical signal.

[0002] Such apparatus is known, for example, from WO95/25011, US-A-5 227 813 and EP-A-0 422 870 and in which the channels are separated one from the next by side walls which extend in the lengthwise direction of the channels. In response to electrical signals, the channel walls are displaceable transverse to the channel axis. This in turn generates acoustic waves that travel along the channel axis, causing droplet ejection as is well-known in the art.

[0003] The last of the aforementioned documents discloses the concept of "multipulse greyscale printing": firing a variable number of ink droplets from a single channel within a short period of time, the resulting "packet" of droplets merging in flight and/or on the paper to form a correspondingly variable-size printed dot on the paper. Figure 1 is taken from the aforementioned EP-A-0 422 870 and illustrates diagrammatically droplet ejection from ten neighbouring printhead channels ejecting varying numbers (64, 60, 55, 40, etc.) of droplets. The regular spacing of successive droplets ejected from any one channel indicates that the ejection velocity of successive droplets is constant. It will also be noted that this spacing is the same for channels ejecting a high number of droplets as for channels ejecting a low number of droplets.

[0004] In the course of experiment, two deviations from the behaviour described in EP-A-0 422 870 have been discovered.

[0005] The first finding is that the first droplet to be ejected from a given channel is slowed by air resistance and may find itself hit from behind by subsequent droplets in the packet travelling in its slipstream and therefore subject to less air drag. First and subsequent droplets of the packet may then merge to form a single, large drop.

[0006] The second finding is that the velocity of such a single, large drop will vary depending on the total number of droplets in the packet that are ejected in one go from a given channel.

[0007] A third finding relates to three-cycle operation of the printhead - described, for example in EP-A-0 376 532 - in which successive channels in a printhead are alternately assigned to one of three groups. Each group is enabled in turn, with enabled channels ejecting a packet of one or more droplets in accordance with in-

coming print data as described above. It has been discovered that the velocity of the single, large drop formed by the merging of such droplets will vary depending on whether the adjacent channel in the same group is also being operated (i.e. 1 in 3 channels) or whether only the next-but-one channel in the same group is being operated (i.e. 1 in 6 channels).

[0008] The variations in velocity outlined above can give rise to significant dot placement errors which, although a known problem per se, can be particularly critical in printheads operating in the multipulse greyscale mode explained above. Here the present inventors have established that a placement error between two or more printed dots that is above one quarter of a pixel pitch can lead to print defects that are detectable by the naked eye. Since multipulse greyscale printheads typically operate at a printing pitch of 360 dots per inch and minimum substrate speeds, packet firing frequencies and printhead-substrate separations of 5 m/s, 5kHz and 1mm respectively, this places an upper limit of 1.25 m/s on the acceptable variation in speed between the droplets that go to form any two adjacent printed dots.

[0009] US 4,513,299 describes ink jet drop-on-demand printing system comprising an ink jet print head having an ink cavity supplied with a suitable ink. An electromechanical transducer is mounted in mechanical communication with the ink cavity, and a source of electrical signals is provided to selectively actuate the transducer to produce an ink drop of a selected size. To produce ink drops of a selected size, the source of electrical signals produces one or more electrical drive signals each separated by a fixed time delay which is short with respect to the drop-on-demand drop production rate. Each electrical drive signal ejects a predetermined volume of ink and all the volumes of ink merge to form a single drop prior to the time ink drops reach the print medium for printing.

[0010] The present invention has as an objective the avoidance of the aforementioned dot placement errors when generated by the phenomena described above and will now be described by way of example by reference to the following diagrams, of which:

Figure 2 illustrates variation in droplet velocity with total waveform duration;

Figure 3a illustrates the waveform used in obtaining the results of figure 2;

Figure 3b illustrates the application of a number of the waveforms of figure 3 in succession;

Figure 4 illustrates variation in droplet velocity with the duration of waveform expansion period;

Figure 5 illustrates an actuating waveform according to the present invention

Figure 6 illustrates variation in droplet velocity with duration of waveform dwell period;

[0011] Figure 2 illustrates the variation in drop velocity with total duration T of a draw-reinforce-release (DRR)

waveform applied repeatedly to the channel of a printhead of the kind mentioned above to generate a packet of droplets. Such a waveform - well known in the art - is illustrated in figure 3a and places a printhead channel initially in an expanded condition (a "draw" as at E), subsequently switches to a contracted condition (a "reinforce" as at RF) and then "releases" (as at RL) the channel back to its original, non-actuated, rest condition. As shown in figure 3a, the draw and reinforce periods of the waveform used to obtain figure 2 are equal and repetition of the waveform results in the ejection of one droplet.

[0012] Figure 3b depicts the application of the waveform several times in immediate succession so as to eject several droplets ("droplets per dot" or "dpd") from a channel so as to form a correspondingly sized dot on the paper. It will be appreciated that this step is repeated for each channel every time the group to which it belongs is enabled and the incoming print data is such that it is required to print a dot. In the experiment used to obtain the data shown in figure 2, channels were repeatedly enabled - and dots were printed - at a frequency of 60Hz.

[0013] As explained above, the droplets in a packet ejected from a channel may all merge in flight to form a single, large drop that hits the substrate to be printed. Alternatively, all droplet merging may take place at the substrate. In a third regime, all the droplets in a packet merge in flight with the exception of the first droplet of the packet which travels ahead of the large, merged drop.

[0014] Figure 2 does not distinguish between these various modes, instead indicating the velocity of the first drop(plet) to hit the substrate as measured at the substrate. It will be seen that the application of a single DRR waveform (1 dpd) of around 4.5  $\mu$ s duration (to eject a single droplet) will result in a velocity of approximately 12m/s per second if only alternate channels in a group are fired (1 in 6 operation) whereas a velocity of around 14 m/s results if every channel in a group is fired (1 in 3 operation). However, applying the same waveform seven times in immediate succession (7 dpd) so as to eject seven droplets results in a velocity of around 37 m/s when operated "1 in 3" and a velocity of around 25 m/s when operated "1 in 6".

[0015] It has been discovered that there are certain advantageous values of total waveform duration T at which the aforementioned variation in velocity is much reduced. In the case of Fig. 2, it will be seen that by operating a printhead with a waveform of approximately 3.8  $\mu$ s duration, the velocity remains fairly constant at around 12 m/s regardless of the number of droplets ejected in one go or the firing/non-firing status of adjacent channels in the same group. Similarly, operation with a waveform of around 7.5 $\mu$ s or greater will result in a fairly constant velocity although, at only 4 m/s, this is less desirable since a droplet ejection velocity of at least 5 m/s, and preferably at least 7 m/s, has been found

necessary for acceptable print quality. Furthermore, greater values of T also result in a greater waveform duration overall and a correspondingly lower dot printing rate.

[0016] Figure 2 was obtained using a printhead of the kind disclosed in the aforementioned WO95/25011 and having a resonant frequency of approximately 250kHz, equivalent to a period of resonance of approximately 4 $\mu$ s. This is reflected in the "1 in 3 / 1 dpd" trace of figure 2 which shows a resonant peak in the velocity, U, of droplets ejected from the printhead when the period of the actuating waveform is equal to 4 $\mu$ s, corresponding in turn to compression and expansion elements of the actuating waveform each being equal to 2 $\mu$ s. As explained in WO95/25011, such a resonant period has in the past been considered as being equal to twice the ratio of closed channel length (L) to the velocity of pressure waves in the ink (c). Consequently, the notation L/c is used hereinafter to denote half the resonant period and, so expressed, the advantageous values referred to above are 1.9L/c and > 3.75L/c respectively.

[0017] It should be noted that at 2 $\mu$ s, this half resonant period is significantly shorter than in similar printheads designed to eject a single ink droplet in any one droplet ejection period - so-called "binary" printing - in which require a greater channel length L to achieve the necessary greater droplet volume. The corresponding reduction in maximum droplet ejection frequency is offset by the fact that only one - rather than a plurality - of drops need be ejected to form the printed dot on the substrate. In contrast, "multipulse greyscale" operation - in which a plurality of droplets form the printed dot - typically requires a printhead in which the half resonant period has a value not exceeding 5  $\mu$ s, preferably not exceeding 2.5  $\mu$ s, in order that sufficiently high repetition frequencies and, secondarily, sufficiently low droplet volumes can be achieved.

[0018] Whilst the aforementioned advantageous values of waveform duration will vary with printhead design, actuation waveform and dot printing frequency, the manner in which they are determined - namely from a graph of the kind shown in figure 2 - will remain the same. The same holds for the value of resonant period for a printhead. For various values of actuation waveform duration T, velocity data U is obtained either from analysis of the landing positions of ejected droplets on a substrate moving at a known speed or - preferably - by observation of droplet ejection stroboscopically under a microscope. It will be appreciated that both methods give an indication of the average velocity of the droplet in the course of its journey between nozzle and substrate.

[0019] As mentioned above, the "DRR" waveform shown in figure 3a need not necessarily have channel contraction and expansion elements that are equal in duration and/or amplitude. Indeed, it is believed that the duration of the expansion element of the waveform may have more influence on the behaviour discussed above

than the duration of the actuation waveform as a whole.

[0020] Figure 4 illustrates the variation with increasing expansion period duration (DR) of the peak-to-peak waveform amplitude (V) necessary to achieve a droplet ejection velocity (U) of 5 m/s. As with figure 2, the printhead was of the kind disclosed in WO95/25011 and having a resonant period,  $2L/c$ , of approximately  $4.4\mu\text{s}$ .

[0021] It will be seen that at values of expansion period duration (DR) of around  $2.5\mu\text{s}$  and  $4.5\mu\text{s}$ , different values of waveform amplitude V are necessary depending on the droplet firing regime. In the case of  $\text{DR}=2.5\mu\text{s}$ , a peak-to-peak waveform amplitude (V) of only 27 volts is required when applying the waveform seven times in immediate succession so as to eject seven droplets (7 drops per dot (dpd)) from one in every three channels ("1 in 3" operation) in multipulse greyscale printing mode. In contrast, a value of  $V=32$  volts is necessary to achieve the same droplet ejection velocity when applying the waveform only once so as to eject a single droplet (1 drop per dot (dpd)) from one in every six channels ("1 in 6" operation).

[0022] In practice, variation of waveform amplitude with droplet firing regime would require complex - and thus expensive - control electronics. The alternative solution of a constant waveform amplitude, whilst simpler and cheaper to implement, would give rise to variations in droplet ejection velocity and consequential droplet placement errors as discussed above.

[0023] The present inventors have discovered, however, that there are values of expansion period duration (DR) at which the droplet ejection velocity remains substantially constant regardless of the droplet firing regime. Operation in such ranges allows waveforms of constant amplitude to be used regardless of operating regime and therefore without the risk of droplet placement errors.

[0024] In the case of figure 4, for example, such constant behaviour occurs with values of DR in the approximate ranges  $1.8\mu\text{s}$  -  $2.2\mu\text{s}$ , with particularly close agreement between velocities being achieved at around  $2.2\mu\text{s}$ , and in the range  $3.0\mu\text{s}$  -  $3.6\mu\text{s}$ , particularly  $3.4\mu\text{s}$ . Expressed in terms of half resonant period,  $U_c$ , these ranges are approximately  $0.8L/c$  -  $1.0L/c$ , particularly  $1L/c$ , and  $1.4U_c$  -  $1.6L/c$ , particularly  $1.5L/c$ . Operation in the lower rather than the higher range gives a lower overall waveform duration which in turn allows a higher waveform repetition frequency. The lower operating voltage for a given droplet speed in the  $1.8\mu\text{s}$  -  $2.2\mu\text{s}$  range also gives rise to correspondingly lower heat generation in the piezoelectric material of the printhead actuator walls. For these reasons, operation in the lower range is to be preferred.

[0025] It should be appreciated that printhead characteristics obtained for a constant droplet ejection velocity (U), as shown in figure 4, will include consistent fluid dynamic effects such as nozzle and ink inlet impedance which are themselves known, for example, from WO92/12014. The characteristics will incorporate vis-

cosity variations, however, brought about by a variation in heating of the ink by the piezoelectric material of the printhead with variation in waveform amplitude (V). Piezoelectric heating of ink in a printhead is explained in WO97/35167, and consequently will not be discussed in further detail here.

[0026] Conversely, printhead characteristics of the kind shown in figure 2 and obtained for a constant waveform amplitude (V) will include consistent heating effects at the expense of varying fluid dynamic effects. It will be appreciated, however, that at those operating conditions according to the present invention whereby waveform amplitude and droplet ejection velocity remain constant regardless of operating regime, fluid dynamic and piezoelectric heating effects will also remain constant. Consequently either type of characteristic is suitable in determining operating conditions according to the present invention.

[0027] Figure 5 illustrates the actuating waveform used in obtaining the characteristics of figure 4, with actuating voltage magnitude being indicated on the ordinate and normalised time on the abscissa. At "C" is indicated the channel expansion period, the duration (DR) of which is varied to obtain the characteristics of figure 6. There follows substantially immediately thereafter a channel contraction period "X" of duration of  $2\text{DR}$ , followed by a period "D" of duration  $0.5\text{DR}$  in which the channel dwells in a condition in which it is neither contracted nor expanded. Following the dwell period, the waveform can be repeated as appropriate to eject further droplets. Such a waveform has been found to be particularly effective in ejecting multiple droplets to form a single, variable-size dot on a substrate without simultaneously causing the ejection of unwanted droplets (so-called "accidentals") from neighbouring channels.

[0028] Furthermore, waveforms of this kind having a particular value of dwell time have been found to be effective in reducing the difference in velocity between single droplet (1 dpd) and multiple droplet (e.g. 7 dpd) operation to be below the level necessary for acceptable image quality.

[0029] Thus the present invention provides a method of operating an inkjet printhead for printing on a substrate; the printhead having a chamber communicating with a nozzle for ejection of ink droplets and with a supply of ink;

the printhead further comprising electrically actuatable means associated with the chamber and actuatable to vary the volume of the chamber in response to an electrical signal, the electrically actuatable means being actuatable a plurality of times in accordance with print tone data thereby to eject a corresponding number of droplets to form a printed dot of appropriate tone on the substrate;

the method comprising the steps of applying a plurality of electrical signals to the electrically actuatable means in accordance with the print tone data;

characterised in that each electrical signal com-

prises a first part to hold the volume of said chamber in an increased state for a first time period and a second part to hold the volume of said chamber in a decreased state for a second time period following said first time period, the length of a time delay between the application of successive signals to said electrically actuable means being selected within the range from 0.45 to 0.85 of said first time period so that any variation in the average velocity at which corresponding droplets travel to said substrate to form said printed dot remains below that which would lead to defects in the printed image detectable by the naked eye, regardless of the number of said droplets ejected to form said printed dot.

[0030] The present inventors have found that with the aid of suitable experiments covering a range of dwell times, a dwell time value can be found at which the average velocity of the droplets in a packet remains within a narrow band, regardless of the number of droplets in that packet. As a result, any variation in the average velocity that does take place between droplet packet of varying size will be less than that which would otherwise give rise to defects in the printed image detectable by the naked eye as explained earlier.

[0031] Preferred embodiments of both aspects of the invention are set out in the description and dependent claims. The invention also comprises droplet deposition apparatus and drive circuit means adapted to operate according to these claims.

[0032] Figure 6 illustrates the results of an experiment of the kind referred to above, the variation in average droplet velocity,  $U$ , being plotted against variation in the length of the dwell period  $D$  of a waveform of the kind shown in figure 5. The length of  $D$  is expressed as a fraction of the length  $DR$  of the expansion period  $C$  which, in the present example, has a length of  $2.2\mu s$  and is equal to half the resonant period. Compression period  $X$  is twice the length of  $C$ , as shown in figure 5.

[0033] It will be seen that the waveform of the kind described above in which the dwell time is equal to  $0.5DR$  results in a separation of only  $0.7m/s$  between a maximum velocity of approximately  $6.7m/s$ , corresponding to a packet of 7 droplets, and a minimum velocity of  $6m/s$  corresponding to a packet of two droplets. This is little over half of the allowable difference of  $1.25m/s$  mentioned above. It is also evident from figure 6 that it would be possible to reduce the dwell time to  $0.45DR$  before exceeding the  $1.25m/s$  limit on velocity difference mentioned earlier, resulting in a shorter - and therefore faster - overall waveform. It is also possible to increase the dwell time a similar amount above  $0.5DR$  - to a dwell time of  $0.55$  - without any significant deleterious effects. Indeed, the slower rate of increase in velocity difference with dwell time at values of dwell above  $0.5DR$  means that the  $1.25m/s$  limit is reached at values of  $DR$  around  $0.85$ . A waveform incorporating such a dwell period would only have approximately 90% of the speed of a waveform incorporating a  $0.45DR$  dwell period, however, and is consequently less desira-

ble.

[0034] The results of figures 4 and 6 were obtained using a waveform of the kind shown in figure 5 having an amplitude in the region of  $40V$ . It will be appreciated, however, that constraints elsewhere in the system may result in a somewhat altered waveform being applied in practice. In particular, rise times in the drive circuitry may result in waveform edges having a greater slope than illustrated in figure 5 or in a slight dwell time between application of expansion and contraction signals. In the latter case, any dwell time will be significantly less than the dwell time between signals.

[0035] In addition to having a half resonant period of approximately  $4.4\mu s$ , the printhead used to obtain the results of figures 4 and 6 also had a nozzle outlet diameter of  $25\mu m$  and employed a hydrocarbon ink of the kind disclosed in WO96/24642. Other parameters were typical, for example as disclosed in the EP 0 609 080, EP 0 611 154, EP 0 611 655 and EP 0 612 623. It will be appreciated, however, that experiments of the kind mentioned in regard to figure 6 can be performed with any printhead and suitable values of dwell period thereby established.

[0036] Whilst specific reference has been made to the apparatus described in WO95/25011 and other documents referred to above, the present invention is considered to be applicable to any printhead employing channels having displaceable side walls. Moreover, some of the advantages set forth above can be enjoyed by applying the present invention to drop-on-demand ink jet apparatus employing other electrically actuable means to eject droplets.

## Claims

1. Method of operating an inkjet printhead for printing on a substrate; the printhead having a chamber communicating with a nozzle for ejection of ink droplets and with a supply of ink;

the printhead further comprising electrically actuable means associated with the chamber and actuable to vary the volume of the chamber in response to an electrical signal, the electrically actuable means being actuable a plurality of times in accordance with print tone data thereby to eject a corresponding number of droplets to form a printed dot of appropriate tone on the substrate;

the method comprising the steps of applying a plurality of electrical signals to the electrically actuable means in accordance with the print tone data;

characterised in that each electrical signal comprises a first part (C) to hold the volume of said chamber in an increased state for a first time period and a second part (X) to hold the volume of said chamber in a decreased state for a second time period following said first time period, the length of a

- time delay (D) between the application of successive signals to said electrically actuable means being selected within the range from 0.45 to 0.85 of said first time period so that any variation in the average velocity at which corresponding droplets travel to said substrate to form said printed dot remains below that which would lead to defects in the printed image detectable by the naked eye, regardless of the number of said droplets ejected to form said printed dot.
2. Method according to Claim 1, wherein the ratio of the length of said time delay to said first period is equal to or less than 0.55.
  3. Method according to Claim 1 or 2, wherein the time delay between the application of successive signals is such that the average velocity at which corresponding droplets travel towards the substrate does not vary by more than 1.25m/s.
  4. Method according to Claim 3, wherein said average velocity does not vary by more than 0.7m/s.
  5. Method according to any preceding claim, wherein said chamber is a channel.
  6. Method according to Claim 5, wherein said first time period is equal to the half resonant period of said channel.
  7. Method according to Claim 6, wherein the half resonant period is less than or equal to 5 $\mu$ s.
  8. Method according to Claim 7, wherein the half resonant period is less than or substantially equal to 2.2 $\mu$ s.
  9. Method according to any of Claims 5 to 8, wherein said electrically actuable means acts to displace a wall of said channel.
  10. Method according to Claim 9, wherein said wall is displaceable transversely of the longitudinal axis of said channel.
  11. Method according to Claim 10, wherein said wall separates two adjacent channels.
  12. Method according to any of Claims 9 to 11, wherein said electrically actuable means effects droplet deposition by means of acoustic waves in the droplet fluid.
  13. Method according to Claim 12, wherein the acoustic waves travel along the longitudinal axis of the channel.
  14. Method according to any preceding claim, wherein said second time period is substantially equal to twice said first time period.
  15. Method according to any preceding claim, wherein the printhead has an array of said chambers, the method further comprising the steps of:
    - applying said electrical signals to said electrically actuable means at a frequency such that the velocity of a droplet ejected in response to said signal is both substantially independent of whether or not chambers in the vicinity of said chamber are similarly actuated to effect droplet ejection simultaneously with droplet ejection from said chamber and substantially independent of the number of droplets to be ejected in accordance with the print tone data.
  16. Method according to Claim 15, wherein successive chambers in the array are regularly assigned to groups such that a chamber belonging to any one group is bounded on either side by chambers belonging to at least one other group, the groups of chambers being sequentially enabled for actuation in successive periods;
    - and wherein said electrical signals are applied to said electrically actuable means at a frequency such that the velocity of a droplet ejected in response to said signal is both substantially independent of whether or not those chambers belonging to the same group as said chamber and which are located closest to said chamber in the array are similarly actuated to effect droplet ejection simultaneously with droplet ejection from said chamber and substantially independent of the number of droplets to be ejected in accordance with the print tone data.
  17. Method according to any preceding claim, wherein the printhead has an array of said chambers, and wherein the first time period of each electrical signal is selected such that the velocity of a droplet ejected in response to said signal is both substantially independent of whether or not chambers in the vicinity of said chamber are similarly actuated to effect droplet ejection simultaneously with droplet ejection from said chamber and substantially independent of the number of droplets to be ejected in accordance with the print tone data.
  18. Method according to Claim 17, wherein successive chambers in the array are regularly assigned to groups such that a chamber belonging to any one group is bounded on either side by chambers belonging to at least one other group, the groups of chambers being sequentially enabled for actuation in successive periods; and wherein the first time pe-

rod of each electrical signal is selected such that the velocity of a droplet ejected in response to said signal is both substantially independent of whether or not chambers belonging to the same group as said chamber and which are located closest to said chamber in the array are similarly actuated to effect droplet ejection simultaneously with droplet ejection from said chamber and substantially independent of the number of droplets to be ejected in accordance with the print tone data.

19. An inkjet printhead for printing on a substrate, the printhead having an array of channels, a series of nozzles each communicating with a respective channel for ejection of droplets therefrom, connection means for connecting the channels with a source of ink, electrically actuatable means associated with each channel for varying the volume of a channel in response to an electrical signal, the electrically actuatable means being actuatable a plurality of times in accordance with print tone data thereby to eject a corresponding number of droplets to form a printed dot of appropriate tone on the substrate;

a drive circuit for applying a plurality of electrical signals to the electrically actuatable means in accordance with the print tone data, **characterised in that** the drive circuit is arranged to apply electrical signals each having a first part to hold the volume of said chamber in an increased state for a first time period and a second part to hold the volume of said chamber in a decreased state for a second time period following said first time period, the length of a time delay between the application of successive signals to said electrically actuatable means being selected within the range from 0.45 to 0.85 of said first time period so that any variation in the average velocity at which corresponding droplets travel to said substrate to form said printed dot remains below that which would lead to defects in the printed image detectable by the naked eye, regardless of the number of said droplets ejected to form said printed dot.

20. A drive circuit for an inkjet printhead for printing on a substrate, the printhead having an array of channels, a series of nozzles each communicating with a respective channel for ejection of droplets therefrom, connection means for connecting the channels with a source of ink, electrically actuatable means associated with each channel for varying the volume of a channel in response to an electrical signal, the electrically actuatable means being actuatable a plurality of times in accordance with print tone data thereby to eject a corresponding number of droplets to form a printed dot of appropriate tone on the substrate;

said drive circuit being arranged to apply a plurality of electrical signals to the electrically actu-

able means in accordance with the print tone data, **characterised in that** the drive circuit is arranged to apply electrical signals each having a first part to hold the volume of said chamber in an increased state for a first time period and a second part to hold the volume of said chamber in a decreased state for a second time period following said first time period, the length of a time delay between the application of successive signals to said electrically actuatable means being selected within the range from 0.45 to 0.85 of said first time period so that any variation in the average velocity at which corresponding droplets travel to said substrate to form said printed dot remains below that which would lead to defects in the printed image detectable by the naked eye, regardless of the number of said droplets ejected to form said printed dot.

## Patentansprüche

1. Verfahren zum Betreiben eines Tintenstrahl-Druckkopfes zum Drucken auf einem Substrat; wobei der Druckkopf eine Kammer hat, die mit einer Düse zum Ausstoßen von Tintentropfen und mit einem Tinten-vorrat in Verbindung steht;

wobei der Druckkopf weiter elektrisch betätigbare Mittel umfasst, die mit der Kammer in Zusammenhang stehen und betätigbar sind, um das Volumen der Kammer in Antwort auf ein elektrisches Signal zu variieren, wobei die elektrisch betätigbaren Mittel mehrmals in Übereinstimmung mit Drucktondaten betätigbar sind, um dadurch eine entsprechende Anzahl von Tröpfchen auszustoßen, um einen gedruckten Punkt eines geeigneten Tons auf dem Substrat auszubilden;

wobei das Verfahren die Schritte umfasst, wonach eine Vielzahl elektrischer Signale auf das elektrisch betätigbare Mittel in Übereinstimmung mit Drucktondaten angewendet werden;

**dadurch gekennzeichnet, dass** jedes elektrische Signal einen ersten Teil (C), um das Volumen der Kammer in einem zugenommenen Zustand für eine erste Zeitdauer zu halten, und einen zweiten Teil (X), um das Volumen der Kammer in einem abgenommenen Zustand für eine zweite Zeitdauer, die der ersten Zeitdauer folgt, zu halten, umfasst, wobei die Länge einer Zeitverzögerung (D) zwischen der Anwendung aufeinander folgender Signale auf das elektrisch betätigbare Mittel innerhalb des Bereichs von 0,45 bis 0,85 der ersten Zeitdauer ausgewählt wird, so dass jede Variation in der mittleren Geschwindigkeit, mit der entsprechende Tröpfchen zu dem Substrat wandern, um den gedruckten Punkt auszubilden, unterhalb jener bleiben, die zu Fehlern bzw. Mängeln in dem gedruckten Bild führen würden, die vom bloßen Auge feststellbar sind, und zwar ungeachtet der Anzahl

der Tröpfchen, die ausgestoßen werden, um den gedruckten Punkt auszubilden.

2. Verfahren nach Anspruch 1, bei welchem das Verhältnis der Länge der Zeitverzögerung zu der ersten Zeitdauer gleich oder weniger als 0,55 ist. 5
3. Verfahren nach Anspruch 1 oder 2, bei welchem die Zeitverzögerung zwischen der Anwendung aufeinander folgender Signale derartig ist, dass die mittlere Geschwindigkeit, mit der entsprechende Tröpfchen in Richtung auf das Substrat wandern, nicht um mehr als 1,25 m/s variiert. 10
4. Verfahren nach Anspruch 3, bei welchem die mittlere Geschwindigkeit um nicht mehr als 0,7 m/s variiert. 15
5. Verfahren nach irgendeinem vorhergehenden Anspruch, bei welchem die Kammer ein Kanal ist. 20
6. Verfahren nach Anspruch 5, bei welchem die erste Zeitdauer gleich der halben Resonanzperiode des Kanals ist. 25
7. Verfahren nach Anspruch 6, bei welchem die halbe Resonanzperiode weniger oder gleich 5  $\mu$ s ist.
8. Verfahren nach Anspruch 7, bei welchem die halbe Resonanzperiode weniger oder im wesentlichen gleich 2,2  $\mu$ s ist. 30
9. Verfahren nach irgend einem der Ansprüche 5 bis 8, bei welchem das elektrisch betätigbare Mittel wirkt, um eine Wand des Kanals zu verlagern. 35
10. Verfahren nach Anspruch 9, bei welchem die Wand quer zur Längsachse des Kanals verlagern ist. 40
11. Verfahren nach Anspruch 10, bei welchem die Wand zwei benachbarte Kanäle trennt.
12. Verfahren nach einem der Ansprüche 9 bis 11, bei welchem das elektrisch betätigbare Mittel eine Tröpfchenablagerung mittels akustischer Wellen in dem Tröpfchenfluid bewirkt. 45
13. Verfahren nach Anspruch 12, bei welchem die akustischen Wellen entlang der Längsachse des Kanals wandern. 50
14. Verfahren nach irgendeinem vorhergehenden Anspruch, bei welchem die zweite Zeitdauer im wesentlichen gleich zweimal der ersten Zeitdauer ist. 55
15. Verfahren nach irgendeinem vorhergehenden Anspruch, bei welchem der Druckkopf ein Feld bzw. Array der Kammern hat, wobei das Verfahren weiter

die folgenden Schritte umfasst:

die elektrischen Signale werden auf das elektrisch betätigbare Mittel bei einer Frequenz so angewendet, dass die Geschwindigkeit eines Tröpfchens, das in Antwort auf das Signal ausgestoßen wird, sowohl im wesentlichen unabhängig davon ist, ob oder ob nicht Kammern in der Nachbarschaft der Kammer ähnlich betätigt werden, um einen Tröpfchenausstoß simultan mit einem Tröpfchenausstoß von der Kammer zu bewirken, als auch im wesentlichen unabhängig von der Anzahl der Tröpfchen ist, die in Übereinstimmung mit den Drucktondaten auszustoßen sind.

16. Verfahren nach Anspruch 15, bei welchem aufeinander folgende Kammern in dem Array bzw. Feld regelmäßig Gruppen derartig zugeordnet werden, dass eine Kammer, die zu irgend einer Gruppe gehört, auf beiden Seiten durch Kammern begrenzt ist, die zu wenigstens einer anderen Gruppe gehören; wobei die Gruppen der Kammern sequentiell zur Betätigung in aufeinander folgenden Perioden freigegeben werden; und wobei die elektrischen Signale auf das elektrisch betätigbare Mittel bei einer Frequenz derartig angewendet werden, dass die Geschwindigkeit eines Tröpfchens, das in Antwort auf das Signal ausgestoßen wird, sowohl im wesentlichen unabhängig ist, ob oder ob nicht jene Kammern, die zu derselben Gruppe wie die Kammer gehören und die sich am nächsten bei der Kammer in dem Array befinden, ähnlich betätigt werden, um einen Tröpfchenausstoß simultan mit einem Tröpfchenausstoß von der Kammer zu bewirken, als auch im wesentlichen unabhängig von der Anzahl der Tröpfchen ist, die in Übereinstimmung mit den Drucktondaten auszustoßen sind.
17. Verfahren nach einem vorhergehenden Anspruch, bei welchem der Druckkopf ein Feld der Kammern hat und bei welchem die erste Zeitdauer eines jeden elektrischen Signals derartig ausgewählt wird, dass die Geschwindigkeit eines Tröpfchens, das in Antwort auf das Signal ausgestoßen wird, sowohl im wesentlichen unabhängig davon ist, ob oder ob nicht Kammern in der Nähe der Kammer in ähnlicher Weise betätigt werden, um einen Tröpfchenausstoß simultan mit einem Tröpfchenausstoß von der Kammer zu bewirken, als auch im wesentlichen unabhängig von der Anzahl der Tröpfchen ist, die in Übereinstimmung mit den Drucktondaten auszustoßen sind.
18. Verfahren nach Anspruch 17, bei welchem aufeinander folgende Kammern in dem Array bzw. Feld Gruppen regelmäßig zugeordnet sind, so dass eine



Kammer, die zu irgendeiner Gruppe gehört, auf beiden Seiten durch Kammern begrenzt wird, die zu wenigstens einer anderen Gruppe gehören, wobei die Gruppen von Kammern sequentiell zur Betätigung in aufeinander folgenden Perioden freigegeben werden; und wobei die erste Zeitdauer eines jeden elektrischen Signals derartig ausgewählt wird, dass die Geschwindigkeit eines Tröpfchens, das in Antwort auf das Signal ausgestoßen wird, sowohl im wesentlichen unabhängig davon ist, ob oder ob nicht Kammern, die zu derselben Gruppe wie die Kammer gehören und die sich am nächsten zu der Kammer in dem Array bzw. Feld befinden, ähnlich betätigt werden, um einen Tröpfchenausstoß simultan mit einem Tröpfchenausstoß von der Kammer zu bewirken, als auch im wesentlichen unabhängig von der Anzahl von Tröpfchen ist, die in Übereinstimmung mit den Drucktondaten ausgestoßen werden.

19. Tintenstrahl-Druckkopf zum Drucken auf ein Substrat, wobei der Druckkopf folgendes umfasst: ein Array bzw. Feld von Kanälen, eine Reihe von Düsen, die mit einem jeweiligen Kanal zum Ausstoß von Tröpfchen in Verbindung stehen, Verbindungsmittel zum Verbinden der Kanäle mit einer Tintenquelle, elektrisch betätigbare Mittel, die mit einem jeden Kanal zum Variieren des Volumens eines Kanals in Antwort auf ein elektrisches Signal in Zusammenhang stehen, wobei das elektrisch betätigbare Mittel mehrmals in Übereinstimmung mit Drucktondaten betätigbar ist, um dadurch eine entsprechende Anzahl von Tröpfchen auszustoßen, um einen gedruckten Punkt eines geeigneten Tons auf dem Substrat zu drucken;

eine Antriebsschaltung bzw. Treiberschaltung zum Anlegen einer Vielzahl von elektrischen Signalen an das elektrisch betätigbare Mittel in Übereinstimmung mit den Drucktondaten, **dadurch gekennzeichnet, dass die Antriebsschaltung bzw. Treiberschaltung angeordnet ist, um elektrische Signale anzulegen, die jeweils einen ersten Teil, um das Volumen der Kammer in einen zugenommenen Zustand für eine erste Zeitdauer zu halten, und einen zweiten Teil, um das Volumen der Kammer in einem abgenommenen Zustand für eine Zweitzeitdauer, die der ersten Zeitdauer folgt, zu halten, haben, wobei die Länge einer Zeitverzögerung zwischen dem Anlegen aufeinanderfolgender Signale an das elektrisch betätigbare Mittel innerhalb des Bereichs von 0,45 bis 0,85 der ersten Zeitdauer ausgewählt wird, so dass jegliche Variation in der mittleren Geschwindigkeit, mit der entsprechende Tröpfchen zu dem Substrat wandern, um den gedruckten Punkt auszubilden, unterhalb jener bleibt, die zu Mängeln bzw. Fehlern in dem gedruckten Bild führen würden, die von dem bloßen Auge feststellbar sind, und zwar ungeachtet der Anzahl der**

Tröpfchen, die ausgestoßen werden, um den gedruckten Punkt auszubilden.

20. Antriebsschaltung bzw. Treiberschaltung für einen Tintenstrahl-Druckkopf zum Drucken auf einem Substrat, wobei der Druckkopf folgendes umfasst: ein Feld bzw. Array von Kanälen, eine Reihe von Düsen, die jeweils mit einem jeweiligen Kanal zum Ausstoß von Tröpfchen davon in Verbindung stehen, Verbindungsmittel zum Verbinden von Kanälen mit einer Tintenquelle, elektrisch betätigbare Mittel, die mit jedem Kanal in Verbindung stehen, um das Volumen eines Kanals in Antwort auf ein elektrisches Signal zu variieren, wobei die elektrisch betätigbaren Mittel eine Vielzahl von Malen in Übereinstimmung mit Drucktondaten betätigbar sind, um dadurch eine entsprechende Anzahl von Tröpfchen auszustoßen, um einen gedruckten Punkt eines geeigneten Tons auf dem Substrat auszubilden;

wobei die Antriebsschaltung bzw. die Treiberschaltung angeordnet ist, um eine Vielzahl elektrischer Signale an das elektrisch betätigbare Mittel in Übereinstimmung mit den Drucktondaten anzulegen, **dadurch gekennzeichnet, dass die Antriebsschaltung bzw. Treiberschaltung angeordnet ist, um elektrische Signale anzulegen, die jeweils einen ersten Teil, um das Volumen der Kammer in einen zugenommenen Zustand für eine erste Zeitdauer zu halten, und einen zweiten Teil, um das Volumen der Kammer in einem abgenommenen Zustand für eine zweite Zeitdauer, die der ersten Zeitdauer folgt, zu halten, haben, wobei die Länge einer Zeitverzögerung zwischen der Anwendung aufeinanderfolgender Signale auf das elektrisch betätigbare Mittel innerhalb des Bereichs von 0,45 bis 0,85 der ersten Zeitdauer ausgewählt wird, so dass eine jede Variation in der mittleren Geschwindigkeit, mit der entsprechende Tröpfchen zu dem Substrat wandern, um den gedruckten Punkt auszubilden, unterhalb jener bleibt, die zu Mängeln im gedruckten Bild führen würde, die von dem bloßen Auge feststellbar sind, und zwar ungeachtet der Anzahl der Tröpfchen, die ausgestoßen werden, um den gedruckten Punkt auszubilden.**

#### Revendications

1. Procédé de commande d'une tête d'impression à jet d'encre pour imprimer sur un substrat, la tête d'impression ayant une chambre en communication avec une buse d'éjection de gouttelettes d'encre et avec une source d'encre ;  
la tête d'impression comprenant en outre des moyens électriquement excitables associés à la chambre et excitables pour faire varier le volume de la chambre en réponse à un signal électrique, les

moyens électriquement excitables étant excitables une pluralité de fois conformément à des données de ton d'impression afin d'éjecter un nombre correspondant de gouttelettes pour former un point imprimé de ton approprié sur le substrat ;

le procédé comprenant les étapes d'application d'une pluralité de signaux électriques aux moyens électriquement excitables conformément aux données de ton d'impression ;

caractérisé en ce que chaque signal électrique comprend une première partie (C), pour maintenir le volume de la dite chambre dans un état augmenté pendant une première durée, et une deuxième partie (X) pour maintenir le volume de la dite chambre dans un état diminué pendant une deuxième durée à la suite de la dite première durée, la durée d'un repos (D) entre l'application des signaux successifs aux dits moyens électriquement excitables étant choisie dans la plage de 0,45 à 0,85 fois la dite première durée de sorte que toute variation de la vitesse moyenne à laquelle des gouttelettes correspondantes se déplacent vers le dit substrat pour former le dit point imprimé reste inférieure à celle qui engendrerait des défauts de l'image imprimée détectables à l'œil nu, quel que soit le nombre de dites gouttelettes éjectées pour former le dit point imprimé.

2. Procédé selon la revendication 1, dans lequel le rapport de la durée du dit repos à la dite première durée est égal ou inférieur à 0,55. 30
3. Procédé selon la revendication 1 ou 2, dans lequel la durée de repos entre l'application de signaux successifs est telle que la vitesse moyenne à laquelle les gouttelettes correspondantes se déplacent vers le substrat ne varie pas de plus de 1,25 m/s. 35
4. Procédé selon la revendication 3, dans lequel la dite vitesse moyenne ne varie pas de plus de 0,7 m/s. 40
5. Procédé selon une quelconque des revendications précédentes, dans lequel la dite chambre est un canal. 45
6. Procédé selon la revendication 5, dans lequel la dite première durée est égale à la demi-période de résonance du dit canal.
7. Procédé selon la revendication 6, dans lequel la demi-période de résonance est inférieure ou égale à 5  $\mu$ s. 50
8. Procédé selon la revendication 7, dans lequel la demi-période de résonance est inférieure ou sensiblement égale à 2,2  $\mu$ s. 55
9. Procédé selon une quelconque des revendications

5 à 8, dans lequel les dits moyens électriquement excitables agissent pour déplacer une paroi du dit canal.

- 5 10. Procédé selon la revendication 9, dans lequel la dite paroi est déplaçable transversalement à l'axe longitudinal du dit canal.
11. Procédé selon la revendication 10, dans lequel la dite paroi sépare deux canaux adjacents. 10
12. Procédé selon une quelconque de revendications 9 à 10, dans lequel les dits moyens électriquement excitables effectuent un dépôt de gouttelettes au moyen d'ondes acoustiques dans le fluide de formation de gouttelette. 15
13. Procédé selon la revendication 12, dans lequel les ondes acoustiques se déplacent le long de l'axe longitudinal du canal. 20
14. Procédé selon une quelconque des revendications précédentes, dans lequel la dite deuxième durée est sensiblement égale au double de la dite première durée. 25
15. Procédé selon une quelconque des revendications précédentes, dans lequel la tête d'impression comporte une série de dites chambres, le procédé comprenant en outre les étapes d'application des dits signaux électriques aux dits moyens électriquement excitables à une fréquence telle que la vitesse d'une gouttelette éjectée en réponse au dit signal est à la fois sensiblement indépendante de ce que les chambres au voisinage de la dite chambre sont ou non excitées de façon similaire pour effectuer une éjection de gouttelette en même temps que l'éjection de gouttelette à partir de la dite chambre, et sensiblement indépendante du nombre de gouttelettes à éjecter en fonction des données de ton d'impression.
16. Procédé selon la revendication 15, dans lequel les chambres successives de la série sont régulièrement affectées à des groupes de sorte qu'une chambre appartenant à un groupe quelconque est délimitée sur chaque côté par des chambres appartenant à au moins un autre groupe, les groupes de chambres étant séquentiellement activés pour excitation dans des périodes successives ;  
et dans lequel les dits signaux électriques sont appliqués aux dits moyens électriquement excitables à une fréquence telle que la vitesse d'une gouttelette éjectée en réponse au dit signal est à la fois sensiblement indépendante de ce que les chambres appartenant au même groupe que la dite chambre et qui sont les plus proches de la dite chambre dans la série sont ou non excitées de fa-

çon semblable pour effectuer une éjection de gouttelette en même temps que l'éjection de gouttelette à partir de la dite chambre, et sensiblement indépendante du nombre de gouttelettes à éjecter en fonction des données de ton d'impression.

17. Procédé selon une quelconque des revendications précédentes, dans lequel la tête d'impression comprend une série de dites chambres, et dans lequel la première durée de chaque signal électrique est choisie de sorte que la vitesse d'une gouttelette éjectée en réponse au dit signal est à la fois sensiblement indépendante de ce que les chambres au voisinage de la dite chambre sont ou non excitées de façon similaire pour effectuer une éjection de gouttelette en même temps que l'éjection de gouttelette à partir de la dite chambre, et sensiblement indépendante du nombre de gouttelettes à éjecter en fonction des données de ton d'impression.
18. Procédé selon la revendication 17, dans lequel les chambres successives de la série sont régulièrement affectées à des groupes de sorte qu'une chambre appartenant à un groupe quelconque est délimitée sur chaque côté par des chambres appartenant à au moins un autre groupe, les groupes de chambres étant séquentiellement activés pour excitation dans des périodes successives ;  
et dans lequel la première durée de chaque signal électrique est choisie de sorte que la vitesse d'une gouttelette éjectée en réponse au dit signal est à la fois sensiblement indépendante de ce que les chambres appartenant au même groupe que la dite chambre et qui sont les plus proches de la dite chambre dans la série sont ou non excitées de façon semblable pour effectuer une éjection de gouttelette en même temps que l'éjection de gouttelette à partir de la dite chambre, et sensiblement indépendante du nombre de gouttelettes à éjecter en fonction des données de ton d'impression.
19. Tête d'impression à jet d'encre pour impression sur un substrat, la tête d'impression comprenant une série de canaux, une série de buses chacune en communication avec un canal respectif pour éjection de gouttelette à partir de ce canal, des moyens de connexion pour connecter les canaux à une source d'encre, des moyens électriquement excitables associés à chaque canal pour faire varier le volume d'un canal en réponse à un signal électrique, les moyens électriquement excitables étant excitables une pluralité de fois conformément à des données de ton d'impression afin d'éjecter un nombre correspondant de gouttelettes pour former un point imprimé de ton approprié sur le substrat ;  
un circuit de commande pour appliquer une pluralité de signaux électriques aux moyens électriquement excitables conformément aux données de

ton d'impression,

**caractérisée en ce que** le circuit de commande est prévu pour appliquer des signaux électriques ayant chacun une première partie, pour maintenir le volume de la dite chambre dans un état augmenté pendant une première durée, et une deuxième partie pour maintenir le volume de la dite chambre dans un état diminué pendant une deuxième durée à la suite de la dite première durée, la durée d'un repos entre l'application des signaux successifs aux dits moyens électriquement excitables étant choisie dans la plage de 0,45 à 0,85 fois la dite première durée de sorte que toute variation de la vitesse moyenne à laquelle des gouttelettes correspondantes se déplacent vers le dit substrat pour former le dit point imprimé reste inférieure à celle qui engendrerait des défauts de l'image imprimée détectables à l'oeil nu, quel que soit le nombre de dites gouttelettes éjectées pour former le dit point imprimé.

20. Circuit de commande d'une tête d'impression à jet d'encre pour impression sur un substrat, la tête d'impression comprenant une série de canaux, une série de buses chacune en communication avec un canal respectif pour éjection de gouttelette à partir de ce canal, des moyens de connexion pour connecter les canaux à une source d'encre, des moyens électriquement excitables associés à chaque canal pour faire varier le volume d'un canal en réponse à un signal électrique, les moyens électriquement excitables étant excitables une pluralité de fois conformément à des données de ton d'impression afin d'éjecter un nombre correspondant de gouttelettes pour former un point imprimé de ton approprié sur le substrat ;

le dit circuit de commande étant prévu pour appliquer une pluralité de signaux électriques aux moyens électriquement excitables conformément aux données de ton d'impression,  
**caractérisé en ce que** le circuit de commande est prévu pour appliquer des signaux électriques ayant chacun une première partie, pour maintenir le volume de la dite chambre dans un état augmenté pendant une première durée, et une deuxième partie pour maintenir le volume de la dite chambre dans un état diminué pendant une deuxième durée à la suite de la dite première durée, la durée d'un repos entre l'application des signaux successifs aux dits moyens électriquement excitables étant choisie dans la plage de 0,45 à 0,85 fois la dite première durée de sorte que toute variation de la vitesse moyenne à laquelle des gouttelettes correspondantes se déplacent vers le dit substrat pour former le dit point imprimé reste inférieure à celle qui engendrerait des défauts de l'image imprimée détectables à l'oeil nu, quel que soit le nombre de dites gouttelettes éjectées pour former le dit point imprimé.

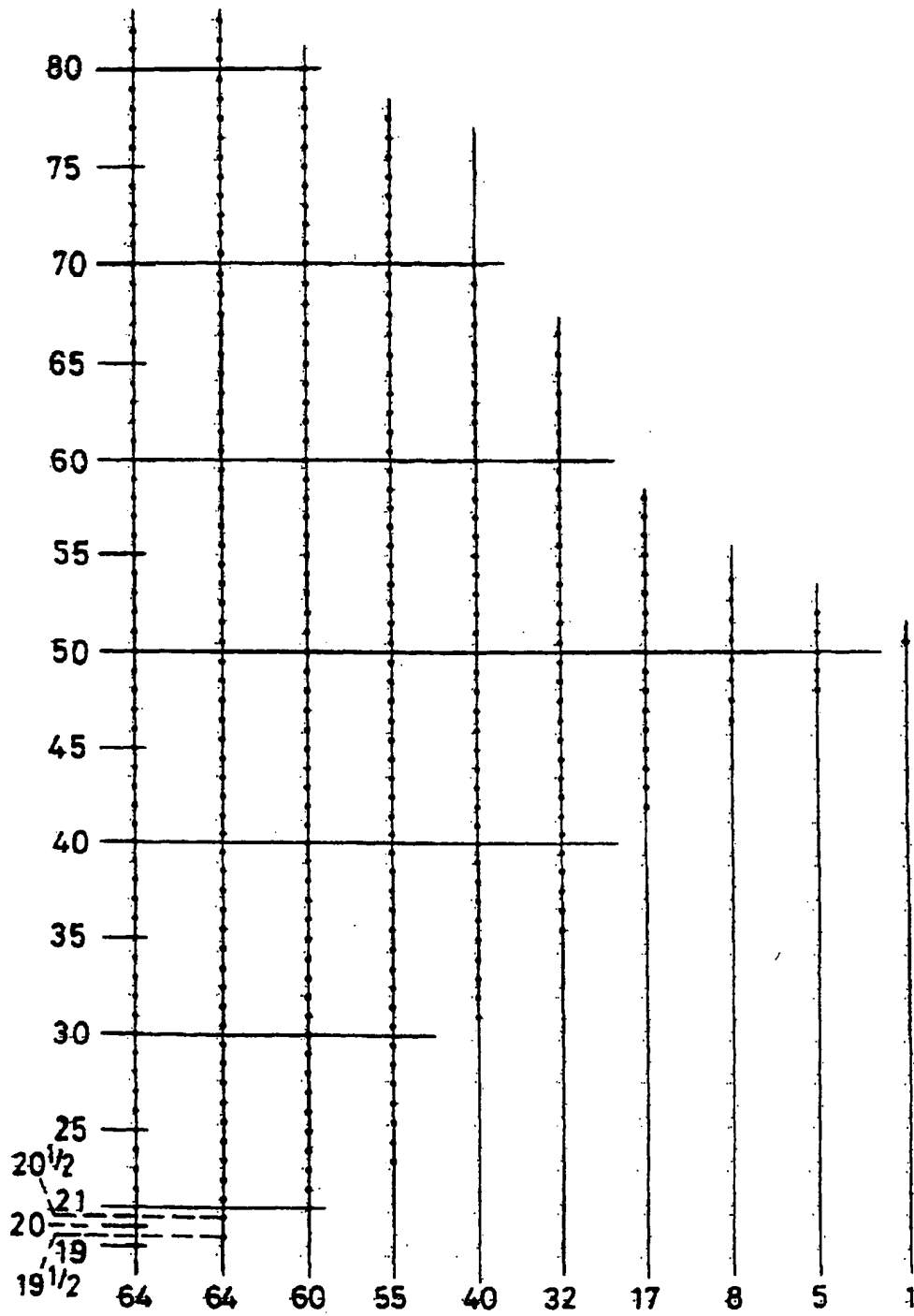


Fig. 1

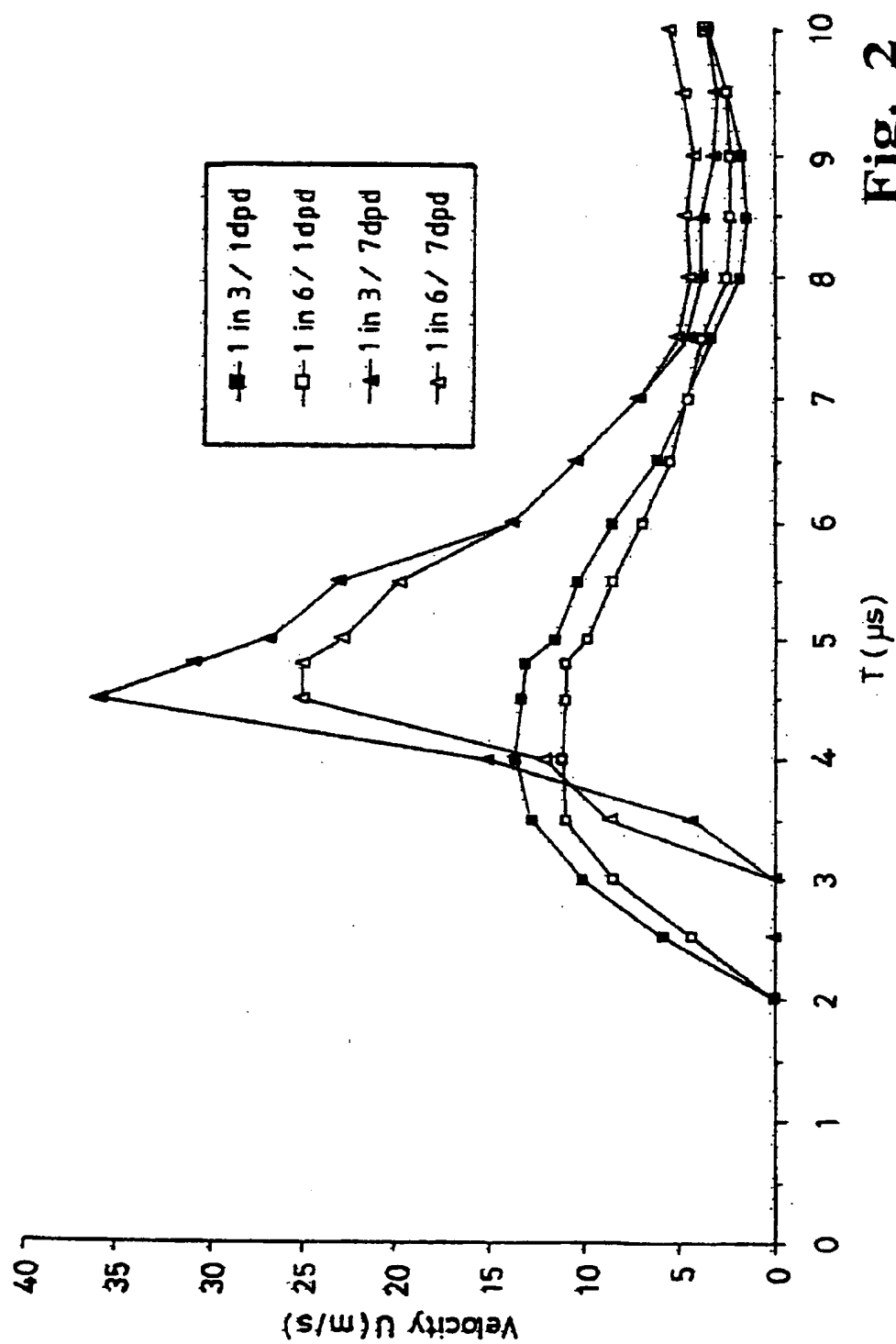
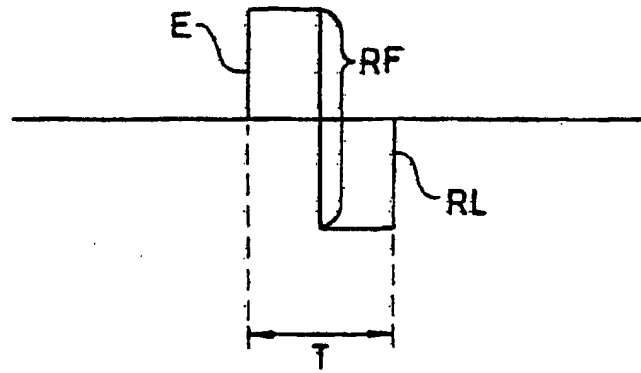
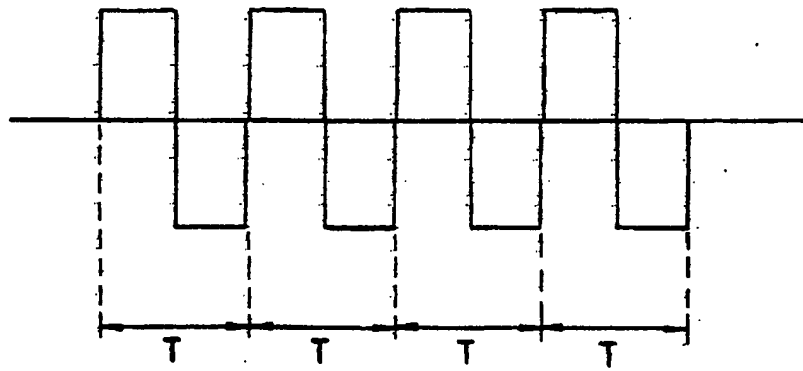


Fig. 2



**Fig. 3A**



**Fig. 3B**

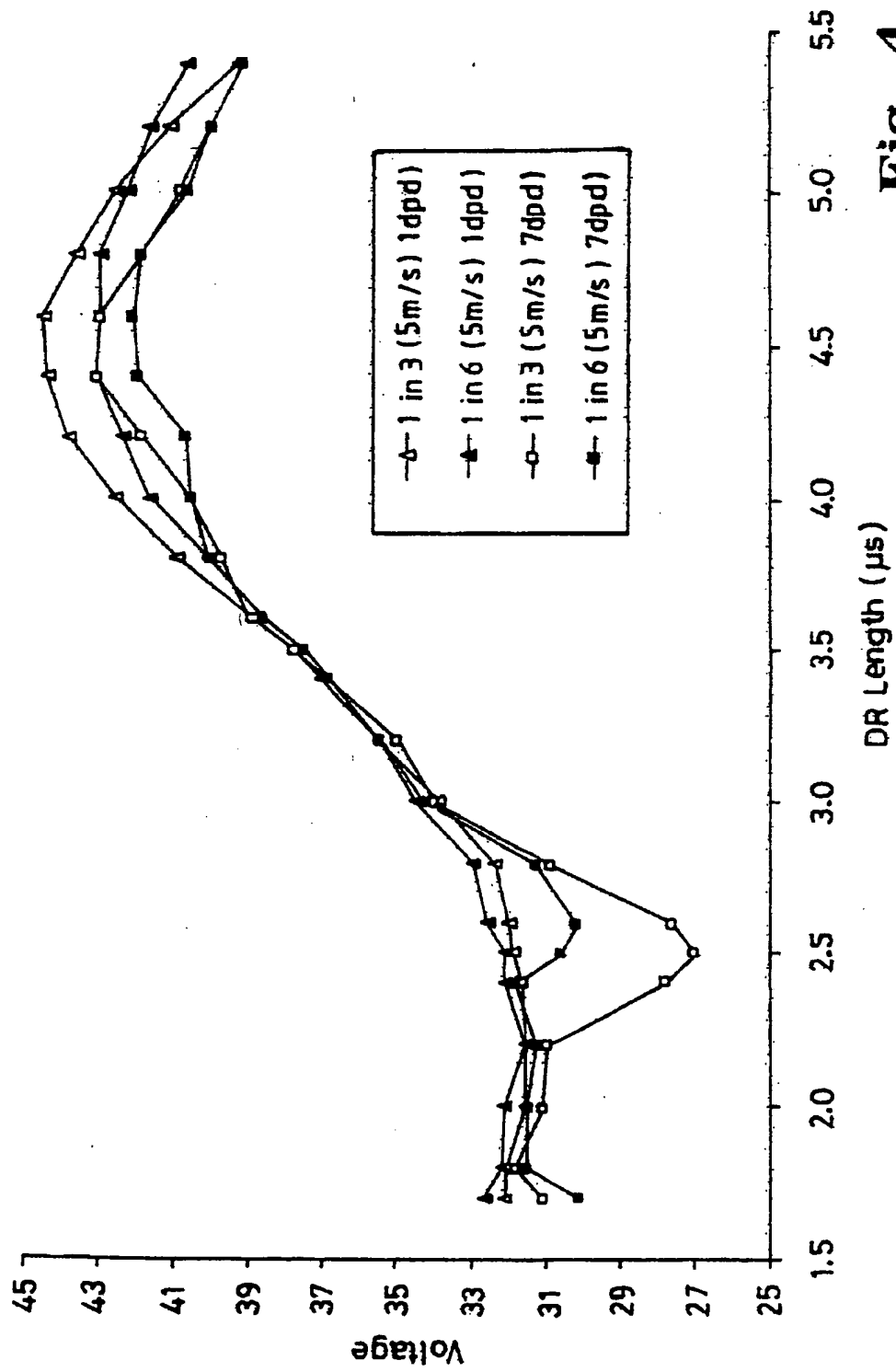
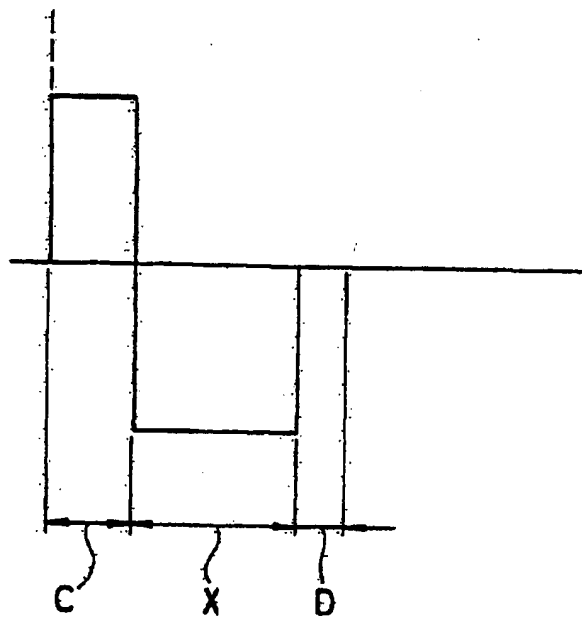


Fig. 4



**Fig. 5**



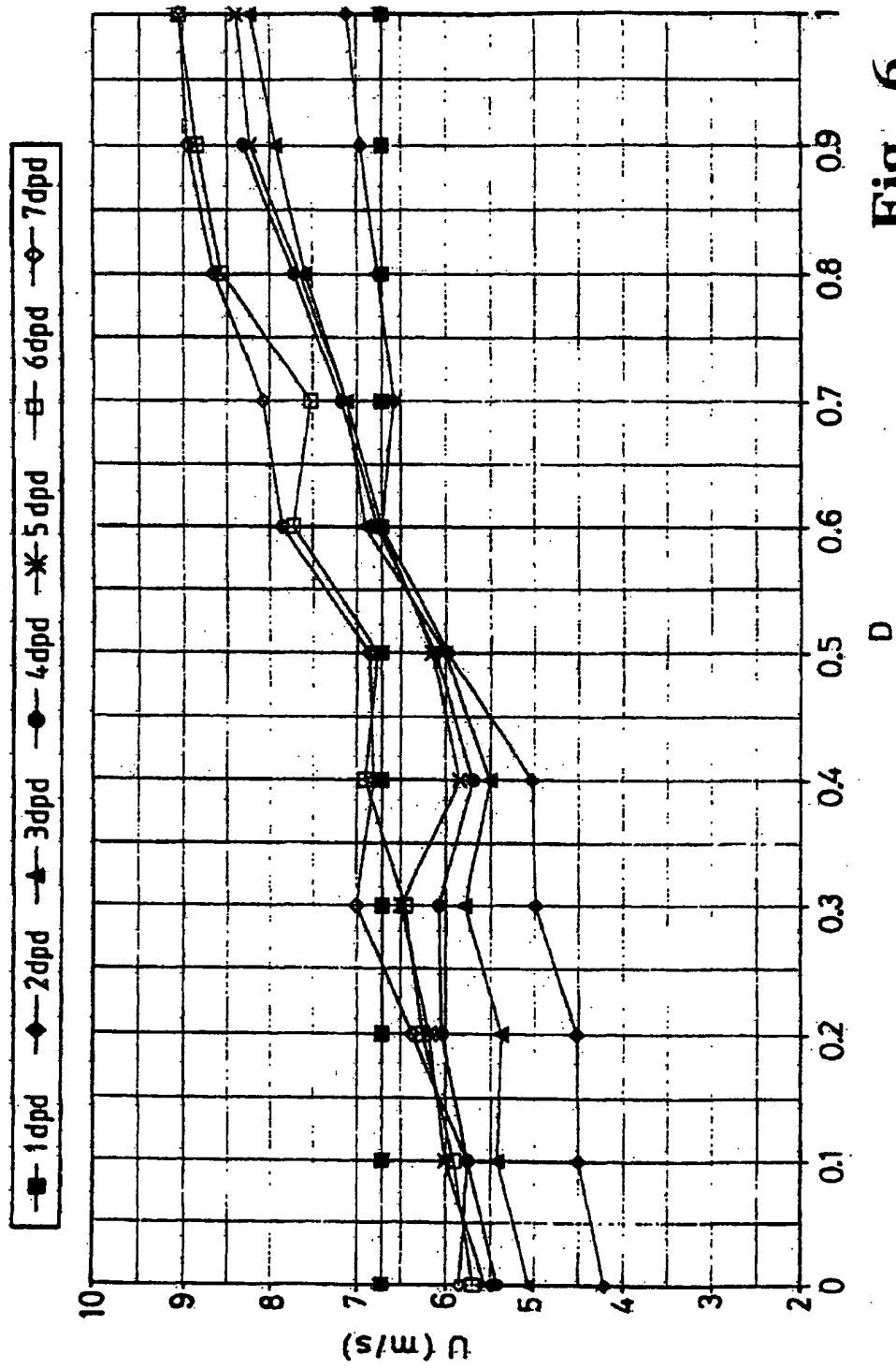


Fig. 6